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AUTHOR Clements, Douglas H.
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ABSTRACT

Educational technology can change the way children think, what they learn, and how they interact with peers and adults, or technology can teach the "same old stuff in the same old way." This paper examines computer use with young children and how computers can be used more effectively. The essay describes changes in the past decade in computer use, noting the increased number of preschools with computers, the drop in the ratio of students to computers, and increased concern over equity of access. The paper examines computer use in learning mathematics and science, and maintains that, although young children make significant gains using computer-assisted instruction software, technology should emphasize problem solving. Examples are given of programs allowing development of problem-solving skills. The essay then examines the computer's role in the home and preschool, suggesting that most children use classroom computers occasionally, mostly for drill-and-practice, although more early childhood teachers are selecting more open-ended programs. Children use instructional software even less at home, even if it is present, and far less often than games. Research suggests that computers are potential catalysts for social interaction and cognitive play, with children's interactions affected by the software being used. The paper considers changes in the adult's role as the nature of computer use has changed, and notes that with careful attention to establishing physical arrangements, giving assistance, selecting software programs, and enhancing learning, adults can optimize the computer's advantages. (Contains 45 references.) (KB)

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Effective Use of Computers with Young Children

Douglas H. Clements

State University of New York at Buffalo

Author information

Douglas Clements, Professor
State University of New York at Buffalo
593 Baldy Hall
North Campus
Buffalo, NY 14260
Wk: (716) 645-3158
Fx: (716) 645-3161

Preferred mailing address and phone:

Douglas Clements
114 Carriage Circle
Williamsville, NY 14221-2164
Hm: (716) 689-3788

e-mail: clements@acsu.buffalo.edu

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Effective Use of Computers with Young Children

Section 3: The Implementation of Mathematics Programs
Topic: The use of technology

Effective Use of Computers with Young Children

Four-year-old Leah was playing Thinkin' Things (Fig. 1). She needed to find a "fripple with stripes and curly hair but not purple." She had the mouse posed over a purple fripple and said, loudly, "Not purple!" Then she moved to a green striped fripple and said "Ha! I think is this is the right one? No!" After another search, she hovered over a correct choice. "Is this one? Yes! Then I click on it." Leah's talking aloud indicates that she is not only learning about attributes and logic, but is developing thinking strategies and "learning to learn" skills.

Technology can change the way children think, what they learn, and how they interact with peers and adults. It can also "teach the same old stuff in a thinly disguised version of the same old way" (Papert 1980). The choice is ours.

Changes in Perspectives

Just a decade ago, only 25% of the licensed preschools had computers. Now almost every preschool has a computer and the ratio of computers to students has dropped from 1:125 in 1984 to 1:22 in 1990 to 1:10 1997. Of course, these are averages and are not representative of every preschool. Also, the amount of time children use these computers may vary widely. We can, nevertheless, expect most children to have one or more computers in their preschools and homes in the 21st century. We must think carefully about how we choose to use computers with preschoolers.

During the same period, research has moved beyond simple questions about technology and young children. For example, no longer need we ask whether the use of technology is developmentally appropriate. Very young children have shown comfort and confidence in using computers. They can turn them on, follow pictorial directions, and use situational and visual cues to understand and reason about their activity (Clements and Nastasi 1993). Typing on the keyboard does not seem to cause them any trouble; in fact, it seems to be a source of pride. Thanks to recent technological developments, even children with physical and emotional disabilities can use the computer with ease. Besides enhancing their mobility and sense of control, computers can help improve their self-esteem. One totally mute 4-year-old diagnosed

with mental retardation and autism began to echo words for the first time while working at a computer (Schery and O'Connor 1992). However, access is not always equitable. For example, children attending schools with high poor and minority populations have less access to most types of technology (Coley, Cradler, and Engel 1997).

Further, no longer is the unique value of technology as a learning device in question. For instance, by presenting concrete ideas in a symbolic medium, the computer can help bridge the two. Research shows that what is "concrete" for children is not what is "physical," but what is meaningful (Clements and McMillen 1996). Computer representations are often more manageable, flexible, and extensible. One group of young children learned number concepts with a computer felt board environment. They constructed "bean-stick pictures" by selecting and arranging beans, sticks, and number symbols. Compared to a real bean-stick environment, this computer environment offered greater control to students (Char 1989). The computer manipulatives were just as meaningful and easier to use for learning.

Learning Mathematics and Science

All this does not mean, however, that all computer experiences are valuable. It depends on what kind of computer software children are using.

Over all types of software, the research picture is moderately positive. Young students make significant learning gains using Computer-Assisted Instruction (CAI) software (Kulik, Kulik, and Bangert-Drowns 1984; Lieberman 1985; Niemiec and Walberg 1984; Ryan 1991). This type of software presents a task to children, asks them for a response, and provides feedback. Leah's use of Thinkin' Things is an example of such software.

Most CAI programs, however, are just plain drill on number and arithmetic. While even these can raise children's skill levels, this should not be our only, or even our main goal. Instead NCTM recommends that we "create a coherent vision of what it means to be mathematically literate both in a world that relies on calculators and computers to carry out mathematical procedures and in a world where mathematics is rapidly growing and is extensively being applied in diverse fields" (National Council of Teachers of Mathematics 1989, pg. 1). This vision

de-emphasizes rote practice on isolated facts. It emphasizes discussing and solving problems in geometry, number sense, and patterns with the help of manipulatives and computers.

For example, using programs that allow the creation of pictures with geometric shapes, children have demonstrated growing knowledge and competence in working with concepts such as symmetry, patterns and spatial order. Tammy overlapped two triangles with opposite orientations (one facing left, the other right) and colored select parts of this figure to create a third triangle that did not exist in the program! Then, she challenged her friend to make a triangle just like it. Not only did preschooler Tammy exhibit an awareness of how she had made this, but she also showed awareness of the challenge it would be to others (Wright 1994). Using a graphics program with three primary colors, young children combined them to create three secondary colors (Wright 1994). Such complex combinatorial abilities are often thought out of reach of young children. Instead, the computer experience led the children to explorations that broadened the boundaries of what they could do.

Computers also help by providing more powerful and flexible "manipulatives." For example, Mitchell wanted to make hexagons using the pattern block triangle. He started off-computer and used a trial-and-error approach, counting the sides and checking after adding each triangle. Using the computer program Shapes, in contrast, he began by planning (Sarama, Clements, and Vukelic 1996). He first placed two triangles, "dragging" them and turning them with the "turn tool." Then he counted with his finger around the center of the incomplete hexagon, visualizing the other triangles. "Whoa!" he announced, "Four more!" After placing the next one, he said, "Three more!" Whereas off-computer, Mitchell had to check each placement with a physical hexagon, the intentional and deliberate actions on the computer lead him to form mental images. That is, he "broke up" the hexagon in his mind's eye and predicted each succeeding placement.

Young children can also explore simple "turtle geometry." They direct the movements of a robot or screen "turtle" to draw different shapes. One group of five-year-olds was constructing rectangles. "I wonder if I can tilt one," mused one boy. He turned the turtle with a simple

mathematical command, "L 1" (turn left one unit), drew the first side...then was unsure about how much to turn at this strange new heading. He finally figured that it must be the same turn command as before. He hesitated again. "How far now?...Oh, it must be the same as its partner!" He easily completed his rectangle (Fig. 2). The instructions he should give the turtle at this new heading were initially not obvious. He analyzed the situation and reflected on the properties of a rectangle. Perhaps most important, he posed the problem for himself (Clements and Battista 1992).

This boy had walked rectangular paths, drawn rectangles with pencils, and built them on geoboards and pegboards. What did the computer experience add? It helped him link his previous experiences to more explicit mathematical ideas. It helped him connect visual shapes with abstract numbers. Perhaps most important, it encouraged him to wonder about mathematics and pose problems in an environment in which he could create, try out, and receive feedback about his own ideas. Such discoveries happen frequently. One preschooler made the discovery that reversing the turtle's orientation and moving it backwards had the same effect as merely moving it forwards. Striking was the significance the child attached to this identity and his overt awareness of it. Though the child had done this previously with toy cars, Logo helped him abstract a new and exciting idea for his experience (Tan 1985). When simple turtle environments are gradually introduced, young children understand and learn from them. They transfer their knowledge to map-reading tasks and interpreting right and left rotation of objects (Clements 1983-84, Cohen and Geva 1989, Kromhout and Butzin 1993, Watson, Lange, and Brinkley 1992). Older children extend their number capabilities. Three five-year-olds determined the correct length for the bottom line of their drawing by adding the lengths of the three horizontal lines that they constructed at the top of the tower: 20 + 30 + 20 = 70 (Clements 1983-84).

Another way of using Logo, emphasizing science, also encourages inclusion. With LEGO-Logo™, children use the Logo language to control LEGO creations, including lights, sensors, motors, gears, and pulleys. Papert (1993) observed some Boston children playing with LEGO and computers. The boys started making trucks right away. The girls made a house. At first, they

traded motors for things they could use to decorate their house. They were not interested in the mechanical, Logo-controlled aspects. Then one day, there was a light in one of the rooms in the house. The Logo code was simple -- on wait 10 off wait 10. Later there were several lights, then a lighted Christmas tree that a motor turned around. This was a soft transition. The girls found their own way into the full use of LEGO-Logo. With Logo, fantasy, technology, mathematics, science, and personal ways of knowing can come together in natural connections rather than stay separate as specialized subjects. One boy puts it well: "If we didn't have the computer, what could we use to say that the electricity should flow and then it should stop? Where would we put our knowledge? We can't just leave it in our heads. We know it, we think it, but our programs would stay in our heads" (Winer and Trudel 1991).

Computer's Role in the Home and Preschool

What is happening in homes and schools? Fortunately, young children are more likely to have computers in their classrooms. Unfortunately, most children use computers only occasionally and usually only because their teachers wanted to add "variety" or rewards to the curriculum. Children use mostly drill-and-practice software; their teachers state that their goal for using computers is to increase basic skills rather than develop problem-solving or creative skills (Becker 1990, Hickey 1993). However, this is changing. More early childhood teachers are choosing open-ended programs based on developmental issues (Haugland 1997).

In the home, children use instructional software, even if present, far less than games. This is especially unfortunate. Placing computers in kindergartners' classrooms for several months significantly increases children's skills; placing them in the home yields greater gains (Hess and McGarvey 1987). We need additional software and programs that bridge the school-home and entertainment-learning gaps.

When children do use computers, how do they interact? Contrary to initial fears, computers do not isolate children. Rather, they serve as potential catalysts for social interaction. Children at the computer spent 9 times as much time talking to peers while on the computer than while doing puzzles (Muller and Perlmutter 1985). Researchers observe that 95% of children's talking during

Logo is related to their work (Genishi, McCollum, and Strand 1985). Children prefer to work with a friend rather than alone. Children make new friends around the computer. There is greater and more spontaneous peer teaching and helping (Clements and Nastasi 1992).

As we saw, the ratio of children to computers near the turn of the century will be 10:1. This meets the recommended minimal ratio. In classrooms with proportionally fewer computers, aggressive behavior may be increased (Clements and Nastasi 1993, Coley, Cradler, and Engel 1997).

Children's interactions at the computer are affected by the software they are using. For example, open-ended programs like Logo foster collaborative group characterized by patterns of goal-setting, planning, negotiation and resolution of conflicts. Drill and practice software, on the other hand, can encourage turn-taking but also engender a competitive spirit. Similarly, game-like programs with aggressive content can engender the same qualities in children (Silvern and Williamson 1987). Games involving cooperative interaction can improve children's social behavior (Garaigordobil and Echebarria 1995). A computer simulation of a Smurf playhouse attenuated the themes of territoriality and aggression that emerged with a real playhouse version of the Smurf environment (Forman 1986). This may be due to features of the computer; in the computer environment, the Smurf characters could literally share the same space and could even jump "through" one another. The "forced" shared space of the computer program also caused children to talk to each other more.

In addition, computers may engender an advanced cognitive type of play among children. In one study, "games with rules" was the most frequently occurring type of play among preschoolers working at computers (Hoover and Austin 1986). So, already prevailing patterns of social participation and cognitive play were enhanced by the presence of computers. In a similar vein, children are more likely to get correct answers when they work cooperatively, rather than competitively, on educational computer games (Strommen 1993).

Changes in the Adult's Role

The nature of computers changes the adults' role as teacher, sometimes subtly. With careful attention to establishing physical arrangements, giving assistance, selecting software programs, and enhancing learning, adults can do much to optimize the computers' advantages.

By altering the physical arrangement of the computers in the classroom, teachers can enhance their social use (Davidson and Wright 1994). Placing two seats in front of the computer and one at the side for an adult can encourage positive social interaction. Placing computers close to each other can facilitate the sharing of ideas among children. Computers that are centrally located as "learning centers" in the classroom invite other children to pause and participate in the computer activity. Such an arrangement also helps keep adult participation at an optimum level. They are nearby to provide supervision and assistance as needed—substantial initial guidance that tapers off—but are not constantly so close as to inhibit the children (Clements 1991).

Adults also have to find a delicate balance in providing assistance. Teachers and parents should give "just enough" guidance, but not too much. Intervening too much or at the wrong time can decrease peer tutoring and collaboration (Emihovich and Miller 1988). On the other hand, without any adult guidance, children tend to "jockey" for position at the computer and use the computer in a turn-taking, competitive manner (Silvern, Countermine, and Williamson 1988). In a similar vein, adults' role has to change in accordance to the changing needs of the child. Initially, adults may need to be more demonstrative, assisting children with problem-solving, setting goals, and planning. However, once they have gained confidence and expertise, adults can recede to being observers and facilitators, ready to help when needed (Clements and Nastasi 1992).

Even more than with print materials, adults have to carefully review and select software materials. For example, drill and practice software, though leading to gains in certain rote skills, has not been as effective in improving the conceptual capabilities of children (Clements and Nastasi 1993). Discovery-based software that encourages and allows ample room for exploration

is more valuable in this regard. Adults must find software that challenges children to solve meaningful problems. The computer should do what textbooks and worksheets do not do well. For example, it should help students connect multiple representations and use animation appropriately. It should encourage multiple solution strategies.

Finally, adults must carefully enhance children's learning. Effective adults structure and guide work with rich programs to ensure children form strong, valid mathematical and scientific ideas. They know that children work best when given open-ended projects rather than asked merely to "free explore" (Lemerise 1993). Children spend more time and actively search for diverse ways to solve designated tasks (Fig. 3). Those who are only encouraged to free explore soon grow disinterested.

Effective adults also raise questions about "surprises" or conflicts between children's intuitions and computer feedback to promote reflection. They pose challenges and tasks designed to make the mathematical or scientific ideas explicit for children. They help children build bridges between computer and other experiences. In particular, they connect computer work closely with off-computer activities. For example, preschoolers who are exposed to developmental software alone show gains in intelligence, non-verbal skills, long-term memory and manual dexterity. Those who also work with supplemental activities, in comparison, gained in all of these areas and improved their scores in verbal, problem solving, and conceptual skills (Haugland 1992). Also, these children spent the least amount of time on computer. A control group that used drill and practice software were on the computer three times as much but showed less than half of the gains that the on- and off- computer group did.

The importance of guiding children to see and build mathematical ideas embedded in software cannot be overemphasized. Most children experience only the surface features of rich programs without such guidance. For example, two preschoolers were trying to fill a shape they made with Kid Pix®2 (Fig. 4a). They were frustrated because the "paint" they were using kept covering the whole picture (Fig. 4b). They figured out on their own that they needed to close the shape. But it was their teacher who encouraged them to talk about their experience, describing

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closed and not closed shapes using the dynamic "filling" action of the computer. Later, their teacher challenged them to figure out which of several shapes were closed (Fig. 4c) and to find other closed and not closed shapes in their world.

Effective adults allow children to use their own approaches. They capitalize on the computer's ability to engage people of different backgrounds, styles, and sexes (Clements 1987, Delclos and Burns 1993). They also see the computer as a new medium for understanding children. Observing the child at the computer provides adults with a "window into a child's thinking process" (Weir, Russell, and Valente 1982). Research has warned us, however, not to curtail observations after a few months. Sometimes beneficial effects appear only after a year. On-going observations also help us chart children's growth (Cochran-Smith, Kahn, and Paris 1988).

Some effective teachers see computers as an opportunity to become pioneers of change—a dramatic change in their professional role. Because they know their children best, they can create successful programs. Frustrated by the lack of good software, Tom Snyder started using the computer to support his classroom simulations of history. Mike Gralish, an early childhood teacher, used several computer devices and programs to link the base 10 blocks and the number system for his children. Today, both these gentlemen are leading educational innovators (Riel 1994).

To learn to be effective computer educators and to keep up with the growing changes in technology, teachers need inservice. Research has established that less than ten hours of training can have a negative impact (Ryan 1993). Some early childhood educators feel anxious about using computers. Others' lack of experience leads them to believe that technology and humanistic education are incompatible. So, extended and intensive experience are recommended. Other researchers have emphasized the importance of hands-on experience and warned against brief exposure to a variety of programs, rather than an in-depth knowledge of one (Wright 1994).

One can use technology to teach the same old stuff in the same way. Integrated computer activities can increase achievement. Children who use practice software about 10 minutes a day learn simple skills. However,

> if the gadgets are computers, the same old teaching becomes incredibly more expensive and biased towards its dullest parts, namely the kind of rote learning in which measurable results can be obtained by treating the children like pigeons in a Skinner box.... I believe with Dewey, Montessori, and Piaget that children learn by doing and by thinking about what they do. And so the fundamental ingredients of educational innovation must be better things to do and better ways to think about oneself doing these things (Papert 1980).

We believe, with Papert, that computers can be a rich source of these ingredients. We believe that having young children use computers in new ways—to pose and solve problems, draw, and do turtle geometry—can help them learn and develop mathematically and scientifically.

References

Becker, Henry J. "How computers are used in United States schools: Basic data from the 1989 I.E.A. Computers in Education Survey." Journal of Educational Computing Research 7 (1990): 385-406.

Char, Cynthia A. Computer graphic feltboards: New software approaches for young children's mathematical exploration. San Francisco: American Educational Research Association, 1989.

Clements, Douglas H. "Supporting young children's Logo programming." The Computing Teacher 11 (1983-84): 24-30.

Clements, Douglas H. "Longitudinal study of the effects of Logo programming on cognitive abilities and achievement." Journal of Educational Computing Research 3 (1987): 73-94.

Clements, Douglas H. Current technology and the early childhood curriculum. In Yearbook in early childhood education, Volume 2: Issues in early childhood curriculum, edited by B. Spodek and O. N. Saracho. 106-131. New York: Teachers College Press, 1991.

Clements, Douglas H., and Michael T. Battista. The development of a Logo-based elementary school geometry curriculum (Final Report: NSF Grant No.: MDR-8651668). Buffalo, NY/Kent, OH: State University of New York at Buffalo/Kent State University, 1992.

Clements, Douglas H., and Sue McMillen. "Rethinking "concrete" manipulatives." Teaching Children Mathematics 2 (1996): 270-279.

Clements, Douglas H., and Bonnie K. Nastasi. Computers and early childhood education. In Advances in school psychology: Preschool and early childhood treatment directions, edited by M. Gettinger, S. N. Elliott and T. R. Kratochwill. 187-246. Hillsdale, NJ: Lawrence Erlbaum Associates, 1992.

Clements, Douglas H., and Bonnie K. Nastasi. Electronic media and early childhood education. In Handbook of research on the education of young children, edited by B. Spodek. 251-275. New York: Macmillan, 1993.

BEST COPY AVAILABLE

Cochran-Smith, Marilyn, Jessica Kahn, and Cynthia L. Paris. When word processors come into the classroom. In Writing with computers in the early grades, edited by J. L. Hoot and S. B. Silvern. 43-74. New York: Teachers College Press, 1988.

Cohen, Rina, and Esther Geva. "Designing Logo-like environments for young children: The interaction between theory and practice." Journal of Educational Computing Research 5 (1989): 349-377.

Coley, Richard J., John Cradler, and Penelope K. Engel. Computers and classrooms: The status of technology in U.S. schools. Princeton, NJ: Educational Testing Service, 1997.

Davidson, Jane, and June Wright, L. The potential of the microcomputer in the early childhood classroom. In Young children: Active learners in a technological age, edited by J. L. Wright and D. D. Shade. 77-91. Washington, D.C.: National Association for the Education of Young Children, 1994.

Delclos, Victor R., and Susan Burns. "Mediational elements in computer programming instruction: An exploratory study." Journal of Computing in Childhood Education 4 (1993): 137-152.

Emihovich, Catherine, and Gloria E. Miller. "Talking to the turtle: A discourse analysis of Logo instruction." Discourse Processes 11 (1988): 183-201.

Forman, George. Computer graphics as a medium for enhancing reflective thinking in young children. In Thinking, edited by J. Bishop, J. Lochhead and D. N. Perkins. 131-137. Hillsdale, NJ: Lawrence Erlbaum Associates, 1986.

Garaigordobil, Maite, and Agustin Echebarria. "Assessment of a peer-helping game program on children's development." Journal of Research in Childhood Education 10 (1995): 63-69.

Genishi, Celia, Pam McCollum, and Elizabeth B. Strand. "Research currents: The interactional richness of children's computer use." Language Arts 62 (1985): 526-532.

Haugland, Susan W. "Effects of computer software on preschool children's developmental gains." Jl. of Computing in Childhood Education 3 (1992): 15-30.

Haugland, Susan W. "How teachers use computers in early childhood classrooms." Journal of Computing in Childhood Education 8 (1997): 3-14.

Hess, R., and L. McGarvey. "School-relevant effects of educational uses of microcomputers in kindergarten classrooms and homes." Journal of Educational Computing Research 3 (1987): 269-287.

Hickey, M. Gail. "Computer use in elementary classrooms: An ethnographic study." Journal of Computing in Childhood Education 4 (1993): 219-228.

Hoover, J., and A. M. Austin. A comparison of traditional preschool and computer play from a social/cognitive perspective. San Francisco, CA: American Educational Research Association, 1986.

Kromhout, Ora M., and Sarah M. Butzin. "Integrating computers into the elementary school curriculum: An evaluation of nine Project CHILD model schools." Journal of Research on Computing in Education 26 (1993): 55-69.

Kulik, C. C., J. Kulik, and Robert L. Bangert-Drowns. Effects of computer-based education of elementary school pupils. New Orleans, LA: American Educational Research Association, 1984.

Lemerise, Tamara. "Piaget, Vygotsky, & Logo." The Computing Teacher (1993): 24-28.

Lieberman, Debra. Research on children and microcomputers: A review of utilization and effects studies. In Children and microcomputers: Research on the newest medium, edited by M. Chen and W. Paisley. 59-83. Beverly Hills: Sage, 1985.

Muller, A. A., and M. Perlmutter. "Preschool children's problem–solving interactions at computers and jigsaw puzzles." Journal of Applied Developmental Psychology 6 (1985): 173-186.

National Council of Teachers of Mathematics. Curriculum and evaluation standards for school mathematics. Reston, VA: The Council, 1989.

Niemiec, R. P., and H. J. Walberg. "Computers and achievement in the elementary schools." Journal of Educational Computing Research 1 (1984): 435-440.

Papert, Seymour. Teaching children thinking: teaching children to be mathematicians vs. teaching about mathematics. In The computer in the school: Tutor, tool, tutee, edited by R. Taylor. 161-196. New York: Teachers College Press, 1980.

Papert, Seymour. The children's machine. Rethinking school in the age of the computer. New York: Basic Books, 1993.

Riel, Margaret. "Educational change in a technology-rich environment." Journal of Research on Computing in Education 26 (1994): 452-474.

Ryan, Alice W. "Meta-analysis of achievement effects of microcomputer applications in elementary schools." Educational Administration Quarterly 27 (1991): 161-184.

Ryan, Alice W. The impact of teacher training on achievement effects of microcomputer use in elementary schools: A meta-analysis. In Rethinking the roles of technology in education, edited by N. Estes and M. Thomas. 770-772. Cambridge, MA: Massachusetts Institute of Technology, 1993.

Sarama, Julie, Douglas H. Clements, and Elaine Bruno Vukelic. The role of a computer manipulative in fostering specific psychological/mathematical processes. In Proceedings of the Eighteenth Annual Meeting of the North America Chapter of the International Group for the Psychology of Mathematics Education, edited by E. Jakubowski, D. Watkins and H. Biske. 567-572. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 1996.

Schery, Teris K., and Lisa C. O'Connor. "The effectiveness of school-based computer language intervention with severely handicapped children." Language, Speech, and Hearing Services in Schools 23 (1992): 43-47.

Silvern, S. B., T. A. Countermine, and P. A. Williamson. "Young children's interaction with a microcomputer." Early Child Development and Care 32 (1988): 23-35.

Silvern, S. B., and P. A. Williamson. "Aggression in young children and video game play." Applied Developmental Psychology 8 (1987): 453-462.

BEST COPY AVAILABLE

Strommen, Erik F. ""Does yours eat leaves?" Cooperative learning in an educational software task." Journal of Computing in Childhood Education 4 (1993): 45-56.

Tan, Lesley E. "Computers in pre-school education." Early Child Development and Care 19 (1985): 319-336.

Watson, J. Allen, Garrett Lange, and Vicki M. Brinkley. "Logo mastery and spatial problem-solving by young children: Effects of Logo language training, route-strategy training, and learning styles on immediate learning and transfer." Journal of Educational Computing Research 8 (1992): 521-540.

Weir, S., S. J. Russell, and J. A. Valente. "Logo: An approach to educating disabled children." BYTE 7 (September 1982):342-360.

Winer, Laura R., and Hélène Trudel. "Children in an educational robotics environment: Experiencing discovery." Journal of Computing in Childhood Education 2 (1991): 41-64.

Wright, June L. Listen to the children: Observing young children's discoveries with the microcomputer. In Young children: Active learners in a technological age, edited by J. L. Wright and D. D. Shade. 3-17. Washington, D.C.: National Association for the Education of Young Children, 1994.

Figure Captions

Figure 1: The person at the door asks the child to find a "fripple" with certain attributes. If the child clicks on a fripple without those attributes, an announcer intones: "That fripple is not exactly the one the customer wants!" If the fripple is correct, it bounces through the door. The program records the level of difficulty the child was on, so that appropriate problems are presented in the next session. Published by Edmark Corp.

Figure 2. A first grader builds up his ideas about rectangles by programming the Logo turtle to draw one tilted.

Figure 3. In "Little, Middle, and Big" children match shoes to characters by size. If they click on the spider, they are given an assigned task, which delighted 3-year-old Julie when she worked on the activity. From Millie's Math House, published by Edmark Corp. Reproduced with permission.

Figure 4. Two girls were filling their building with colors and chose the last area (a). However, to their surprise, the "paint can" filled the entire area (b). Later, the teacher made up some other closed and not closed shapes for these children to explore with the paint can (c). The program is Kid Pix® 2, ©1994, Broderbund Software. Reproduced with permission.

Figure 1

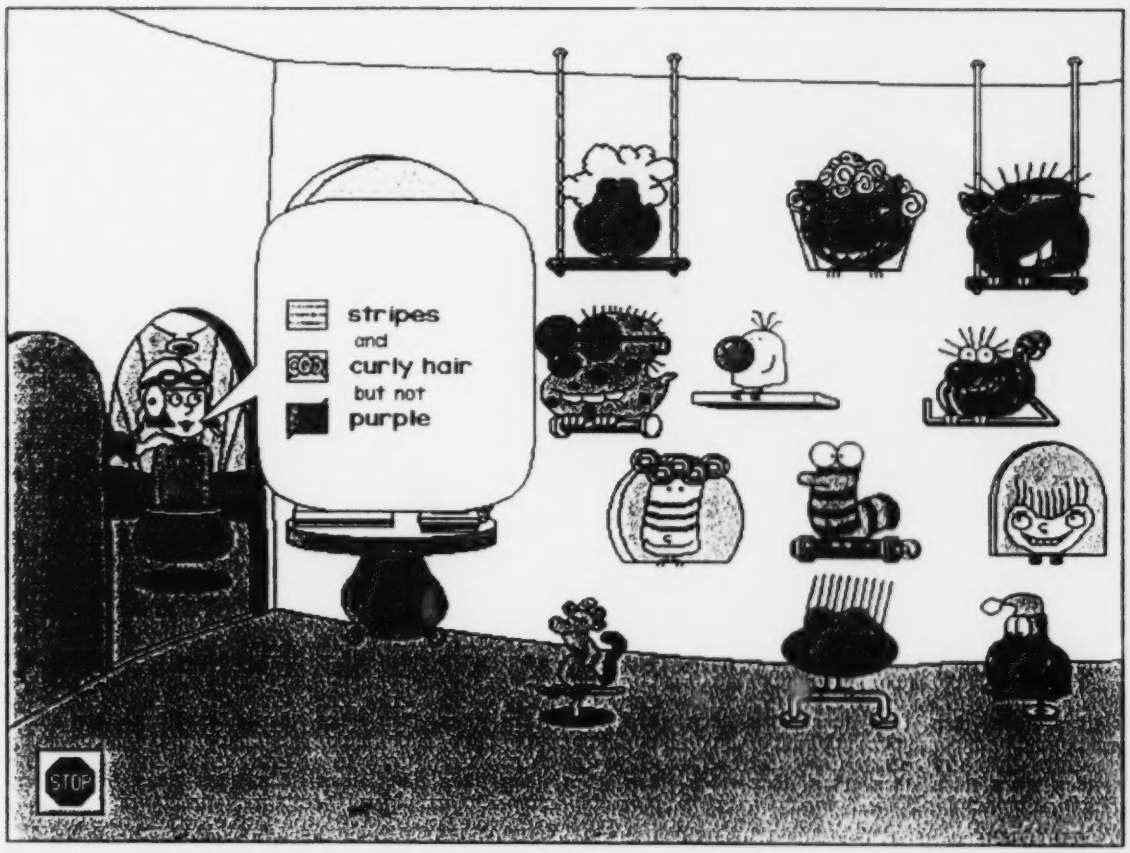

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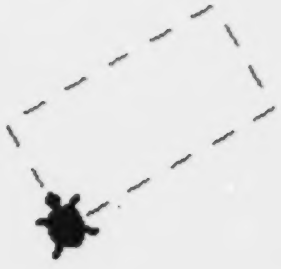
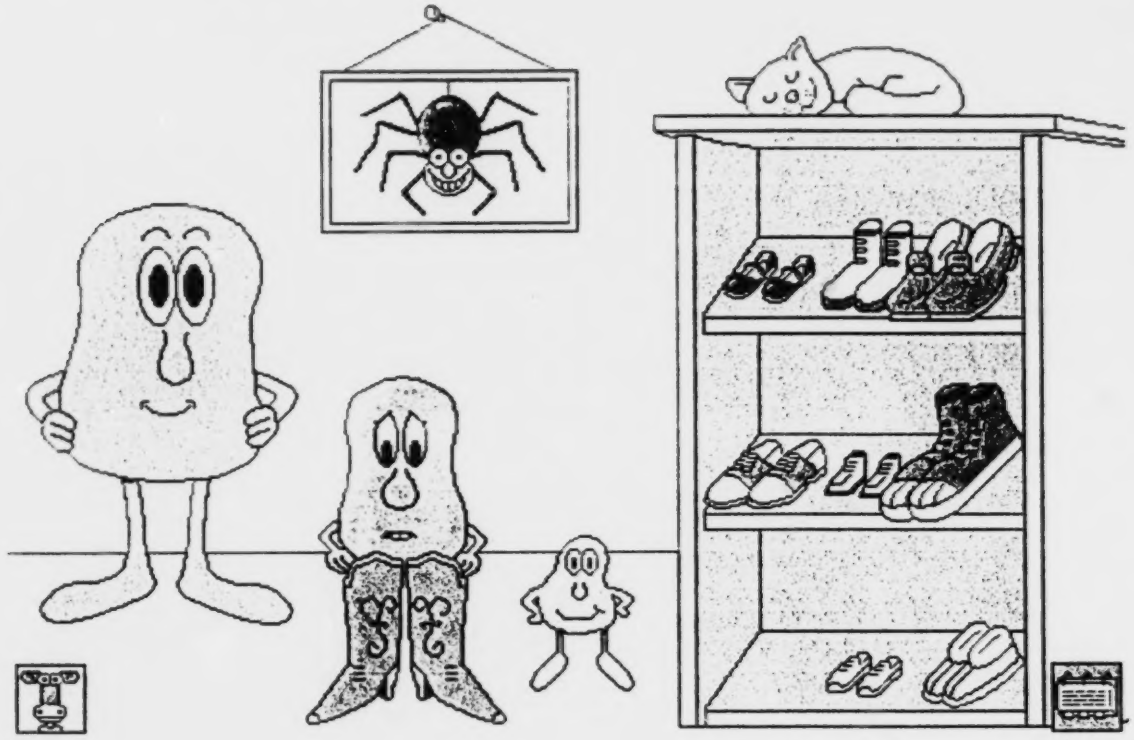
Figure 2



L 1	Turn left one (30°) unit
F 5	Forward 5 units
R 3	
F 10	
R 3	
F 5	
R 3	
F 10	
R 3	

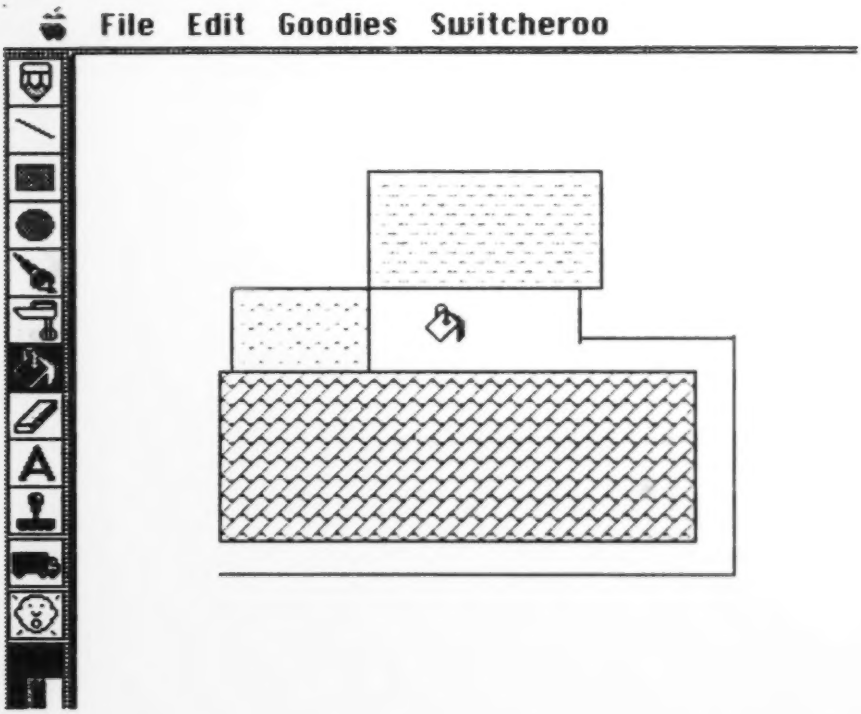
Figure 3



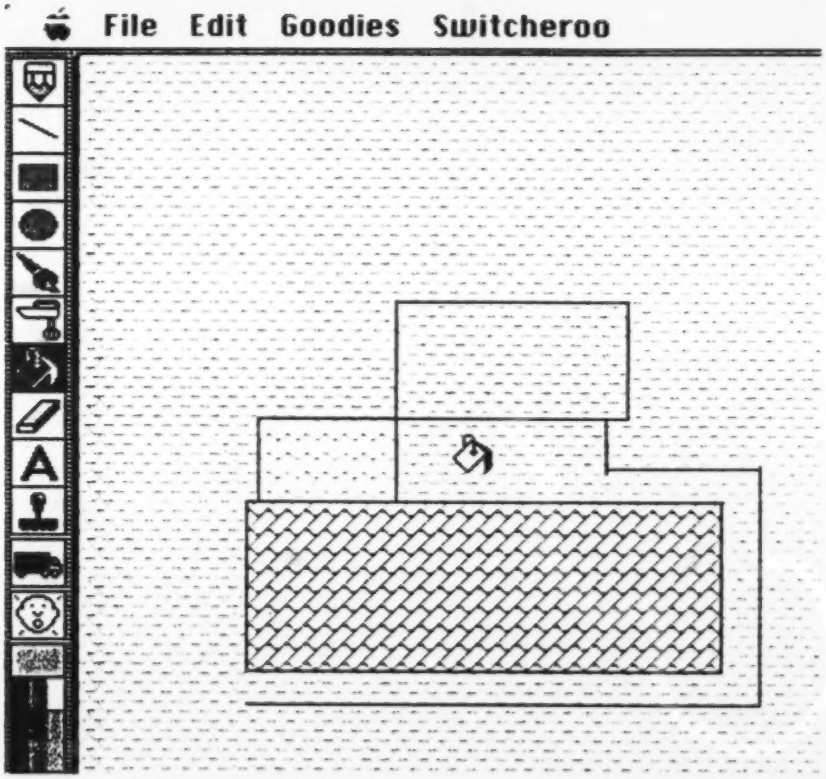
BEST COPY AVAILABLE

Figure 4

a.



b.



c.